PRODUCTION OF METHANE FROM POULTRY MANURE

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ABSTRACT

Poultry industry is a fast growth industry globally in line with high demand in the Halal meat at Islamic countries especially in Malaysia. Increasing number in broiler production creates a lot of environment issues. The recent stunning issue that attracts the attention of the public is about 400 tons of unsolved chicken dung in Selangor that arisen air, water and soil pollution. Fermentation process is the ideal way to solve the problem with win-win situation. Besides producing clean energy with low carbon emission, the sludge obtained after fermentation process is very suitable for landfill as fertilizer. There are 3 same size carboys with 25 liter volume fabricated as fermenters. They are fed-batch with inoculums fermenter, fed-batch without inoculums fermenter and lastly a batch fermenter. After adding 17 liters of sample with 10% TS w/v for each fermenter, the fermenters are purged with pure nitrogen gas for 30 minutes and later placed inside a fabricated polytank with heating system as water bath to maintain the temperature within 55 degree Celsius which is thermophile anaerobic condition. An additional of 1.7 liters of sewage sludge (inoculums) is added to the inoculums fermenter .The quantity of gas produced is checked and recorded every days by gas displacement system and the gas composition is checked gas analyzer once a week. For fed-batch fermenters, one sixth of 17 liters is withdrawn once a week, at the same time, same amount of fresh diluted sample is pumped in by using peristaltic pump. By comparing batch with and without inoculums fermentation, applications of inoculums in batch fermentation shorten the lag phase and leads to a shorter fermentation cycle in batch system. By comparing the same thermophile system between batch and fed-batch fermentation process, both of the process give similar result in term of biogas production and methane gas composition during lag phase. However, the biogas production for thermophile fed-batch system keep maintaining at log phase whereas thermophile batch system encounter its' stationary phase at the day 14^{th} and death phase at day 40^{th}. In short, application of inoculums in fermentation accelerates the biogas production and fed-batch fermentation is suitable for commercial purpose as the biogas produced is continuous with low down time.

ABSTRAK

Industri ternakan berkembang pesat sejajar dengan permintaan yang tinggi terhadap daging Halal di negara Islam terutamanya di Malaysia. Produksi ayam ternakan yang banyak membawa impak kepada alam sekililing sehingga menimbulkan isu-isu seperti yang berlaku di Selangor,di mana kira-kira 400 tan tahi ayam tidak dapat dilupuskan dan menyebabkan penecemaran udara, air serta tanah yang teruk. Proses penapaian adalah cara yang ideal untuk menyelesaikan masalah ini dengan 'win-win' situasi. Selain dapat menghasilkan tenaga bersih dengan pengeluaran karbon yang rendah, enapemar yang diperolehi adalah sangat sesuai untuk dijadikan sebagai baja. Terdapat tiga jenis fermenter, fed-batch fermenter tanpa inocula, batch fermenter tanpa inocula, dan batch fermenter dengan inocula. Tiga-tiga fermenter ini diubahsuai daripada tiga 25 liter carboys. Selepas 17 liter 10% TS w/v sampel dimasukkan dalam fermenter, gas nitrogen telah disalur masuk kedalam fermenter selama 30 minit untuk menyingkirkan kandungan oksigen dalam fermenter. Selepas itu, fermenter direndam dalam tangki poli untuk mengekalkan suhu fermenter sebanyak 55 ℃. 1.7 liter inocula telah ditambah masuk ke inocula fermenter. Kuantiti gas yang dihasilkan telah direkodkan setiap hari, komposisi gas telah dianalisis sekali seminggu dengan menggunakan Gas Analyzer. Sebanyak 3 liters sampel dikeluarkan dari fed-batch fermenter sekali seminggu, pada masa yang sama, 3 liters sampel baru dipam masuk dengan bantuan pam peristalsis. Dengan membandingkan biogas yang dihasilkan di batch inocula dengan batch tanpa inocula fermenter, penggunaan inocula dalam penapaian batch dapat memendekkan lag phase serta menyebabkan kitaran penapaian yang pendek. Dengan membandingkan batch dan fed-batch penapaian, kedua-dua proses memberikan hasil yang sama bagi kuantiti biogas yang dihasilkan serta komposis methane yang dihasilkan pada lag phase. Namun demikian, biogas yang dihasilkan oleh penapaian fed-batch mengekalkan pada log phase manakala penapaian batch menghadapi stationary phase pada hari ke-14 serta death phase pada hari ke-40. Sebagai kesimpulan, penggunaan inocula dalam penapaian dapat mempercepatkan penghasilan biogas. Selain itu, penapaian fed-batch adalah sesuai untuk tujuan komersial kerana biogas yang dihasilkan daripada cara ini adalah berterusan dengan "down time" yang singkat.

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LIST OF SYMBOLS

℃	Degree Celsius
℉	Degree Fahrenheit
%	Percentage
×	Times
Wt%	Weight Percentage
w/v	Weight per Volume
±	Plus and Minus
L	Liter
ml	Milliliter
cm	Centimeter
KG	Kilogram
Min	Minutes

LIST OF ABBREVIATIONS

TS	Total Solid
AD	Anaerobic Digestion
CH_4	Methane
CO_2	Carbon Dioxide
pH	Potential Hydrogen
HRT	Hydraulic Retention Time
SRT	Solid Retention Time
PVC	Polyvinyl Chloride
PSM	Projek Sarjana Muda
POME	Palm Oil Mill Effluent

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Poultry is defined as domestic fowls reared for the table, eggs or feathers (Mike Johanns, 2011). There are about 10,000 species of birds in the world but only 12-13 species can be considered as poultry; such as chicken, ducks, turkeys, capons, geese, etc. (Md. Mukhlesur Rahman, 2009). Rapid economic and population growths in Malaysia fuel the massive increase in demand-driven consumption for food of animal origin especially the poultry (Paraguas, 2006). According to the report issued by Malaysia's Department of Veterinary Services, over the 2000-2010 periods, the local consumption of chicken livestock has increased from 635,000.21 metric tons to 1,013,000 metric tons which is the highest per capita consumption rates in the world for chicken (Abbott, 2010).

The demand on poultry is high in Malaysia because it is the cheapest source of meat protein moreover poultry is a halal product which is homogeneous to all religions and ethnics all around the world (Paraguas, 2006). The concept of halal is associated with food products which are of high quality in term of cleanliness, sanitation and compliance with religious requirement (Fayed, 2011). Subsequently, the production cycle time for poultry is relatively short and profitable under the industrialized production system (Tey & Yeong-Sheng, 2009).

Owing to the high demand on poultry meat in Malaysia, it leads to rapid growths in broiler (chicken meat) production in poultry industry (FLFAM). There are about 3,391 broiler grower farms in Malaysia and near about 26 parent stock farm companies in the Peninsular part of Malaysia (FLFAM, 2007). Along with the increasing

production of broiler, the amount of poultry manure is also rising. The daily excrements of a laying hen can be estimated with 138g/day (25% dry substance) and 90g/day (40% dry substance) of a broiler. A non-appropriate treatment of poultry manure can lead to soil and groundwater pollution; threaten environment and humans' health besides supporting the spread of disease (Roeper et. al., 2005). However, poultry manure especially chicken dropping can be a beneficial commodity if it has been treated properly.

1.2 PROBLEM STATEMENT

The dramatically increment of poultry farm in Malaysia has risen a lot of environment issues and public community problems. A chicken farm located in Kuala Sungai Baru, Melaka has disseminated chicken dropping smell and troubled the residents of vicinity about 6 years. The seriousness of the chicken manure odour issue comes to the extent that causes dizziness, dry throat and lung infections among the residents (New Straits Time, 2009). Furthermore, Selangor state government has ordered a poultry farm in Sungai Buloh to shut down temporarily to remove the 400 tons of chicken dropping which causes unpleasant odour and flies problems to the nearby residents (Zavier, 2010). This issue is no longer an fresh issue for developed countries like Japan, Korea and also European's countries because the application of anaerobic digestion technique is well-developed but it is a great problem when comes to third world countries likes Malaysia, Thailand, Indonesia, etc.

This study will be conducted to determine the efficiency of methane production by using fed-batch reactor, operating at thermophilic temperature range (± 55℃) with regular feed amount of manure every 42 days to maintain the anaerobic fermentation at exponential phase.

1.3 RESEARCH OBJECTIVES

Research objectives of this experiment are:

1. To study the efficiency of fed-batch fermentation towards methane production.
2. To study the effect of inoculums in batch fermentation.
3. To investigate the quality of the biogas produced.

1.4 RESEARCH SCOPE

In order to achieve these objectives, the following scopes have been identified to limit the scope of study;

1.4.1 To produce methane gas from raw chicken manure by anaerobic digester.

1.4.2 To investigate the time taken to bring an anaerobic digester of raw chicken manure to maximum bacterial activity.

1.4.3 To analyze the percentage of methane composition from the biogas yield by using gas analyzer and sample probe.

1.4.4 To compare the production rate of biogas between digester with inoculums and digester without inoculums.

1.5 RATIONALE AND SIGNIFICANCE OF STUDY

The significances of conducting this research are to improve the production rate of methane gas by using fed-batch reactor as a renewable and clean source of energy. The environment problem can be solved in a more efficient and environmental friendly way instead of incineration and dumping at estate area which will lead to serious ground, water and air pollution. Besides, this is a commercial project which highly demanded by foreign and local poultry investors.

All in all, this research is marketable with win-win situation. Besides producing clean energy for farm usage, it can protect our environment by reducing pollution as well.

CHAPTER 2

LITERATURE REVIEW

2.1 ANAEROBIC DIGESTION

Anaerobic digestion is a biological process that involves the breakdown of organic material by a microbial population that lives in an environment with little or no oxygen (Warmer Buletin, 2008). The term 'anaerobic' means literally without air. Although anaerobic digestion can occur naturally within a landfill, the term generally describes an artificially accelerated operation in closed vessels (Friends of The Earth, 2007). Almost all of the organic materials like waste paper, leftover food, industrial effluents, sewage, animal waste and manure can be processed with anaerobic digestion (Warmer Buletin, 2008). During anaerobic treatment process, organic nitrogen compounds are degraded to ammonia, phosphorus compounds are degraded to orthophosphates, sulfur to hydrogen sulfide, and sodium, calcium, and magnesium are converted to a variety of salt. Through appropriate process, the inorganic constituents like ammonia, hydrogen sulfide, and orthophosphate can be converted to a variety of marketable products. When organic matter is decomposed in an anaerobic environment, the bacteria produce biogas by converting putrid organic materials to a mixture of methane, carbon dioxide and trace amounts of other gaseous, nutrient rich organic slurry, and other valuable inorganic products.

The biogas generated during anaerobic digestion can be used as fuel or as a chemical feedstock. Subsequently, the effluent of the process containing particulate and soluble inorganic and organic materials can be separated into its particulate and soluble constituents. The particulate solids can be sold as fertilizer from the poultry farm while the nutrient rich liquids are applied to the land or vegetable farm (Burke, 2001).

2.1.1 Definition of Biogas

Biogas is a by-product of the anaerobic breakdown of organic matter like animal manure or agriculture waste in the farm. It is a clean and environment friendly renewable fuel. Biogas consists of a mixture of methane, carbon dioxide and small amounts of nitrogen, hydrogen, hydrogen sulfide, and water vapour. Methane is the most crucial component of biogas because it is a flammable gas that can be used for cooking; generate electricity, heat and hot water systems, refrigeration, and even use in engine. The heat content of biogas is according to the amount of methane and is around 600 BTUs per cubic foot.

Table 2.1: Chemical Composition of Biogas

Components	**Household waste**	**Wastewater treatment plants sludge**	**Agricultural wastes**
CH_4 % vol	50-60	60-75	60-75
CO_2 % vol	38-34	33-19	33-19
N_2 % vol	5-0	1-0	1-0
O_2 % vol	1-0	< 0.5	< 0.5
H_2O % vol	6 (à40 °C)	6 (à40 °C)	6 (à40 °C)
Total % vol	100	100	100
H_2S mg/m^3	100 - 900	1000 - 4000	3000 – 10 000
NH_3 mg/m^3	-	-	50 - 100
Aromatic mg/m^3	0 - 200	-	-
Organochlorinated or organofluorated mg/m^3	100-800	-	-

*Data obtained from “The Biogas” from http://www.biogas-renewable-energy.info/biogas_composition.html

2.1.2 Bioconversion Process of Turning Organic Materials into Fuel

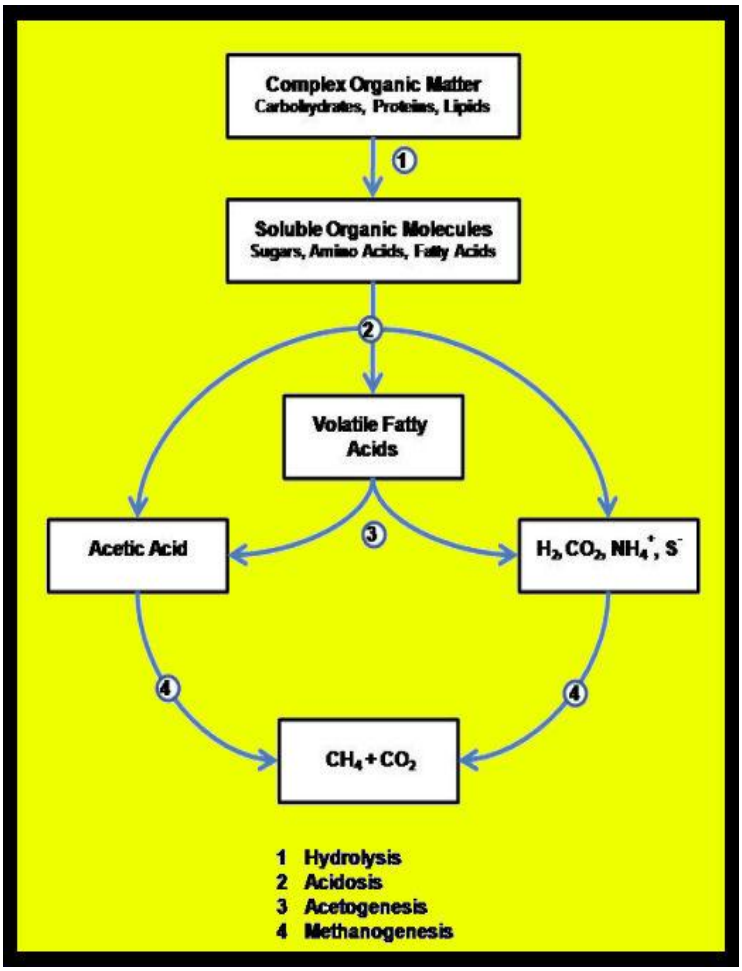

Figure 2.1: Steps in anaerobic digestion (Hamilton, 2010)

Anaerobic digestion (AD) is carried out by a group of bacteria which approximately more than 100 different anaerobic microbes working together to convert organic matter to biogas and inorganic constituents (Burke, 2001). These bacteria are organized into a number of interlinked communities. AD is a multi-stage process that primarily consists of four steps; they are hydrolysis, acidogenenisis, acetogenisis, and methanogenisis (Hamilton, 2010).

Hydrolysis is the phase of anaerobic digestion where insoluble or complex organic polymers such as carbohydrate, cellulose, proteins and lipids are broken down and liquefied by enzymes produced by hydrolytic bacteria into simpler organic molecules. The release of extra-cellular enzymes by a variety of bacteria hydrolyzes the

complex organic matter into simple sugars, amino acids, and fatty acids (Friend of The Earth, 2007).

Acidogenesis is where simple organic molecules are further broken down by acidogenic bacteria (acid-forming bacteria) into volatile fatty acids-principally acetic acid (vinegar) and producing carbon dioxide, hydrogen sulfide and ammonia as byproducts (Friend of The Earth, 2007). Acidogenesis and hydrolysis are normally lumped together and called anaerobic fermentation (Hamilton, 2010).

Acetogenesis is where the simple molecules from acidogenesis which is fatty acids are digested by acetogens bacteria into carbon dioxide, hydrogen and mainly acetic acid. Acetogenesis along with acidogenesis represents the transition from simple organic molecules to the methanogenic substrates.

Methanogenesis is where methanogenic substrates such as volatile fatty acids, hydrogen gas, carbon dioxide gas, acetic acids and water have been utilized by methanogens to form methane. Methanogens in methanogenesis process consists of two main camps depending on the pathway they use to produce methane. Hydrotrophic methanogens reduce CO_2 and H_2 into CH_4 and H_2O exclusively whereas acetotrophic methanogens convert volatile fatty acids and some of the simple organic compounds to CH_4 and CO_2.

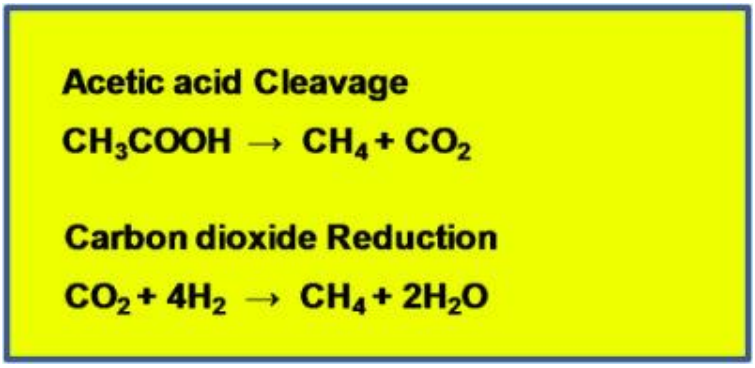

Figure 2.2: Major pathways of methane (CH_4) formation (Hamilton, 2010)

2.2 Phase of Microbial Community Growth

The growth of methanogens or human beings is similar with the growth pattern shown below if the communities of organism do have ample food supply, sufficient room to expand and also absence of predators or competing organisms (Hamilton, 2010). Microbial growth curve consists of five phases; they are lag phase, growth phase, decline phase, stationary phase and death phase (Abedon, 1998).

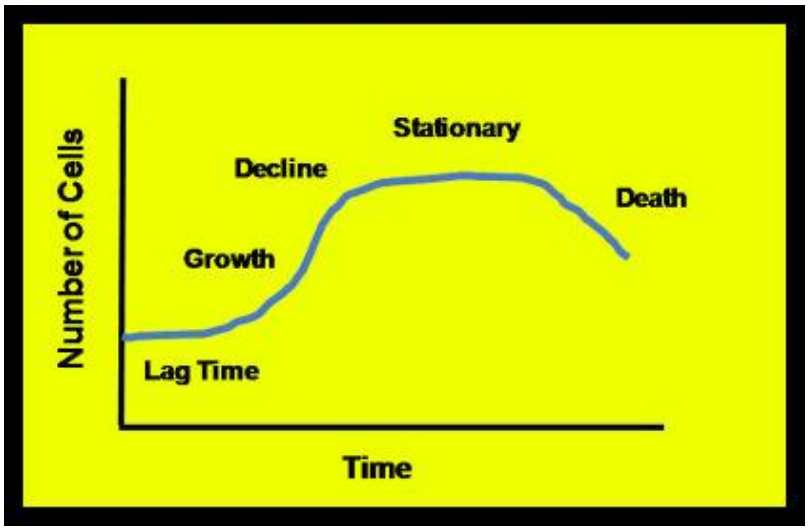

Figure 2.3: Generalized microbial growth curve (Hamilton, 2010)

Lag phase occurs as the organisms adapt to new environment or medium. Upon a change in medium from rich environment to poor environment, there is always a lag before division resumes. As an example, stationary phase of E.coli placed in an excess of sterile broth will undergo a lag phase which allow them to expand in cell size but do not divide. The bacteria will start to divide once they have achieved the size of a cell which is about to divide during log phase. In other words, there is no change in the quantity of bacteria but an increase in mass (Abedon, 1998). "The length of the lag phase is determined in part by characteristics of the bacterial species and in part by conditions in the media---both the medium from which the organisms are taken and the one to which they are transferred. Some species adapt to the new medium in an hour or two; others take several days. Organisms from old cultures, adapted to limited nutrients and large accumulated wastes, take longer to adjust to a new medium than do those transferred from a relatively fresh, nutrient-rich medium" (Black, 1996, p. 138).

The next is growth phase or known as log phase and exponential phase which is a physiological state where the population doubles in number every generation time (Fankhauser, 2008). Food is not limiting during growth phase and the population expands rapidly then divide, thus the bacteria rapidly decreasing in mass while increasing in number (Hamilton, 2010). For example, if there are 10 methanogens present at time 0 during log phase, and 100 methanogens present at time 10, then at time 20 there will be 10,000 cells present (Abedon, 1998). Then it follows by decline phase where the bacterial growth slows down and started to meet the shortage of food supply (Hamilton, 2010).

During stationary phase, the food supply become limiting causes the rate of bacterial division equals the rate of bacteria death, in other words, viable bacteria number remains constant (Fankhauser, 2008). It is a physiological adaption to bacteria excess where bacteria is too crowded with high concentration causes the environment is no longer able to support the requirement of exponential growth (Abedon, 1998). During stationary phase, the microbial community goes into hibernation and the reproduction does not cease until the death rate approaches the reproduction rate (Hamilton, 2010).

Death phase or endogenous growth phase occurs when a limited food supply is exhausted or an inhibiting element causes the death rate exceeds the birth rate. The end products of a community's metabolism are referred to the inhibitory elements which cause endogenous growth in the communities (Hamilton, 2010).

In short, anaerobic digestion is the work of a mixed community of organisms where they taking up the end products of other communities as food supply. The mixed community in the anaerobic digester assists one another in order to get the final product which is biogas. "The beauty of anaerobic digestion is that it is the work of a mixed community of organisms. The toxic end product of one community is the food supply of another. Acid forming bacteria consume the simple sugars that might inhibit hydrolytic communities. Methanogens use the acids formed in fermentation to produce CH_4 and CO_2. And in the end, CH_4 and CO_2 leave the digester as biogas" (Hamilton, 2010).

2.3 Digester Start-up

Materials that contain methanogens such as biosolids from a sewage treatment plant and sludge from an active manure treatment lagoon or known as inoculum are commonly applied into digester to initiate the anaerobic digestion so that to make sure that there is a viable population of methane producing microbes, it is known as a "hot start" (Hamilton, 2010). Inoculum function in seeding the feedstock with an active anaerobic culture which is rich in methanogens to initiate activity and reduce any lag time required to bring the digester on line (Kirk and Faivor, 2010). In some cases, digester is established by a "cold start" which means that manure is slowly added to a liquid filled digester without the addition of inoculum until biogas starts to produce. Hot starts are definitely reacts faster than cold starts. Basically, a hot start takes between one to six months to bring a digester to reach steady-state but it is depending on the digester type used as well. As for a cold start, it may take six to a year time to bring the digester on line (Hamilton, 2010).

2.4 Factor Controlling the Conversion of Poultry Manure to Biogas

The objectives of this study are to investigate the yield of methane from poultry manure (chicken manure) in fed-batch fermentation medium, to study the efficiency of fed-batch fermentation towards methane production and lastly to analyze the quality of the biogas produced. In order to achieve the objectives, there are seven factors need to be take in consideration, they are reproduction time, temperature, steady food supply, hydraulic retention time (HRT), solid retention time (SRT), oxygen, pH.

2.4.1 Reproduction Time

To increase the efficiency of anaerobic digester in producing methane gas, the microbial communities must be designed to remain in exponential phase. Reproduction time is known as doubling rate of an organism which is very important in maintaining the microbial communities in exponential phase as this is the time taken by a population to double in size (Hamilton, 2010). Hence, it is very crucial to make sure that the food supply does not limit the microbes' communities in producing the biogas.

2.4.2 Temperature

The endurable temperatures ranges for anaerobic microbes' communities are from below freezing to above 135℉ (57.2℃). The methane producing bacteria, methanogens thrive best under two temperature ranges which are thermophilic (54.4℃) and mesophilic (36.7℃). Degradation and biogas production occur faster at thermophilic range rather than mesophilic range. This is because thermophilic methanogens are fast growing with the reproduction time of 10 to 15 days only whereas mesophilic methanogens has a 30 days reproduction time which is approximately 2 times slower than thermophilic methanogens. However, thermophilic methanogens are highly sensitive to disturbances, they are not able to tolerate at wide range of temperature which centred on 55℃ and sensitive to the temperature changes in feed materials. In addition, higher temperature of thermophilic digestion has an advantage in completely destructing the weed seeds and pathogenic organisms, but produces an odorous effluent if compared to mesophilic digestion (Burke, 2001). On the other hand, mesophilic methanogens is able to operate in a wide band of temperature and functioning optimally at 35℃.

In order to optimize the production of methane gas, the anaerobic digester must be maintained at a constant temperature so that the bacterial activity will not affect by the rapid changes.

2.4.3 Steady Food Supply

Food is very vital for microbes' reproduction and growth; hence a steady food (manure) supply in the digester is very important in maintaining the microbial growth in exponential phase so that the food does not limit the growth of microbes. Methanogens is able to go dormant if the food is insufficient. The benefit of this criterion is, long periods of inactivity in anaerobic digester can be easily getting restart. Besides, burst of biogas production will occur when there is sudden elevation in feeding, which causes foaming in the digester.

2.4.4 Hydraulic Retention Time (HRT)

Anaerobic digestion normally occurs in liquid form which designed to retain the manure for several periods. If the microbes in the reactor are completely suspended in the reactor then HRT is the number of days the microbes retain in the tank with zero net flow. The HRT equals to the volume of the remaining liquid in the reactor divided by the flow rate.

$$HRT=V/Q$$

HRT is vital as it shows us the time of bacterial growth and also the conversion of organic materials to biogas. The population of microbes within the reactor is considered stable when the reproduction time of the microbes equals the HRT of a completely mixed reactor. "Wash out" will occur when the HRT is shorter than the reproduction time which means that the leaving microbes are greater than the one being produced (Burke, 2001).

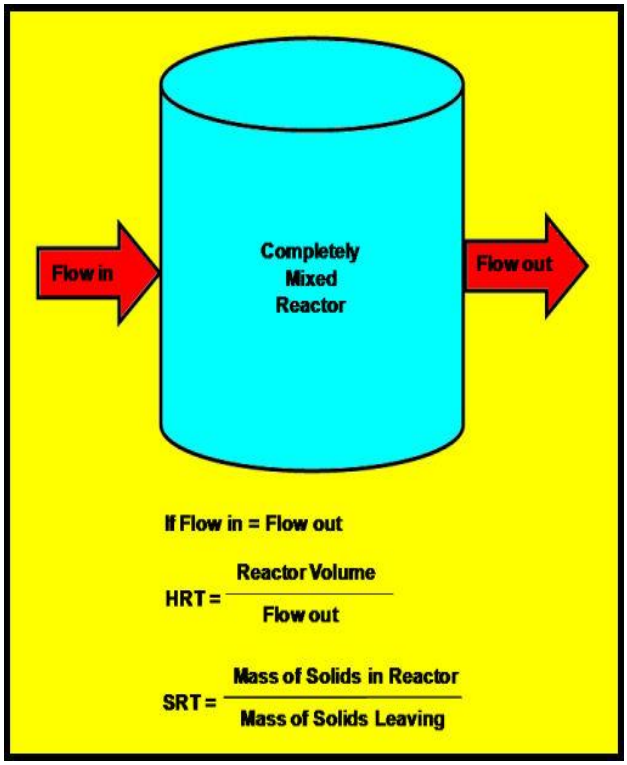

Figure 2.4: Relationships between reactor volume, flow, solids mass, and retention times in a completely mixed reactor. (Hamilton, 2010)

2.4.5 Solids Retention Time (SRT)

Solids retention time (SRT) plays role in maintaining digester stability and controlling the conversion of solids to gas. The microbial population in the anaerobic digester remains stable when the cell retention time equal to reproduction time of cell. SRT can be obtained by dividing the quantity of solids maintained in the digester with the quantity of solids leaving the digester each day.

In most cases, mass of living cells is hard to be measured rather than total mass of solid particles suspended in liquid, thus, SRT can be applied in approximating the cell retention time. For example, a screen is set up on the outlet of the digester to trap the leaving microbes, then; cell retention time can be calculated by dividing the mass of microbes maintained inside the digester with the mass of microbes trapped at the screen each day.

$$SRT = \frac{(V)(Cd)}{(Qw)(Cw)}$$

Where V is the digester volume; Cd is the solids concentration in the digester; Qw is the volume wasted each day and Cw is the solids concentration of the waste (Burke, 2001).

2.4.6 Oxygen

Methanogens react well at oxygen free condition; even existence of least amount of oxygen will cause poison in the methanogens community. Methanogens indeed is strict anaerobes unlike acid forming bacteria which is more tolerant to oxygen. Therefore, the existence of oxygen in anaerobic digester will boost the production of carbon dioxide and lead to the reduction of methane gas concentration.

2.4.7 pH

The optimum pH for methane producing bacteria (Methanogens) is neutral to slightly alkaline environment (pH 6.6 to 7.6). In anaerobic digestion, acid forming bacteria is always growing much quicker than methane producing bacteria. If acid forming bacteria grows too fast, it means that more and more acid (Acetic acid) which is methanogens substrate will be produced. When the production of methanogens substrate is faster than the bacteria can consume, it will cause excess acid builds up in the digester. pH drops in anaerobic digester will inhibit the activity of methanogens and causes low productivity or zero production of methane gas. However, within an anaerobic digester, it exists naturally a pH buffer system, with carbonate-bicarbonate and organic acid-ammonia being the most crucial buffers.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 THERMOPHILIC FERMENTATION SYSTEM FABRICATION

Thermophilic fermention system consisted of three parts. They were anaerobic fermenter fabrication, water displacement system fabrication, and temperature relay system fabrication. These fabrications will be described in detail at following section.

3.1.1 FERMENTER FABRICATION

Basically, there were four fermenters had been fabricated for fed-batch fermenter, batch without inocula fermenter, batch with inocula fermenter and the last one as spare fermenter. The materials needed were four 25L carboys, four rubber stoppers, twelve units of valves, twelve pieces of 13cm long metal tubes, twenty four units of clampers, rubber tubes and silicon.

Firstly, each rubber stoppers were marked with a same angle triangle shape as shown in figure 3.1. Then three holes had been drilled at each angle of the triangle by using drilling machine. Twelve pieces of 13cm long metal tubes had been cut and bended 90 degree.